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Strain localization in unsaturated soils with large deformation

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ABSTRACT

Strain localization is a ubiquitous feature of granular materials undergoing nonhomogeneous deformation. In unsaturated porous media, how the localized deformation band is formed depends crucially on the degree of saturation, because fluid in the pores of a solid imposes a volume constraint on the deformation of the solid. When fluid flow is involved, the inception of the localized deformation band also depends on the heterogeneity of a material, which is quantified in terms of the spatial variation of density, the degree of saturation, and matric suction. We present a mathematical framework for coupled solid-deformation/fluid-diffusion in unsaturated porous media that takes into account material and geometric nonlinearities [1, 2]. The framework relies on the continuum principle of thermodynamics to identify an effective, or constitutive, stress for the solid matrix, and a water retention law that highlights the interdependence of degree of saturation, suction, and porosity of the material. We discuss the role of heterogeneity, quantified either deterministically or stochastically, on the development of a persistent shear band. We derive bifurcation conditions [3] governing the initiation of such a shear band. This research is inspired by current testing techniques that allow nondestructive and noninvasive measurement of density and the degree of saturation through high-resolution imaging [4]. The numerical simulation of an unsaturated sand sample under plane strain condition demonstrates that the bifurcation manifests itself not only on the loading response curve, but also in (S_r, v, $-\vartheta_w$) space.